Circular Economy Research in the Built Environment: A Theoretical Contribution

CIRCULAR ECONOMY RESEARCH IN THE BUILT ENVIRONMENT: A THEORETICAL CONTRIBUTION

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ABSTRACT

Circular economy is quickly gaining momentum across numerous research fields. The founding principles of circular economies lie in a different perspective on, and management of, resources under the idea that an ever-growing economic development and profitability can happen without an ever-growing pressure on the environment. As such, the built environment has a lot to contribute, being the sector with the greatest environmental impacts. However, the few existing cases of current research in the built environment from a circular economy perspective seem to have just replaced the 3R principle (reduce, reuse, recycle) with the new 'buzz-word'. In this paper we argue that a significantly different research approach is necessary if the circular economy is to keep up to its promise of being a new paradigm for sustainability. We therefore propose a framework to formulate building research from within a circular economy perspective. The framework is built around six pillars and acknowledges the key role of interdisciplinary research and that of both bottom-up and top-down initiatives to facilitate the transition to 'circular' buildings. Although theoretical in nature, the framework has been tested against current discourse about buildings and circular economies and it has proven a valuable tool to cluster existing initiatives and highlight missing interdisciplinary links. As such it can provide a valuable starting point to contribute to the theoretical foundations of building research from within the new paradigm of circular economies and also shape future research directions.

INTRODUCTION

There are many different schools of thought on the circular economy (CE) (Ellen MacArthur Foundation, 2016); however the shared founding principles lie in the better management of resources. The role of the built, and particularly the urban, environment is crucial. Cities occupy only 3% of the Earth's land but account for around 70% of energy consumption and carbon dioxide emissions (UN, 2016). While buildings provide the essential infrastructure for civilization and our need for shelter, they also create an ecological threat in terms of resource consumption and depletion, air quality, and pollution of soil and water (Naustdalslid, 2014). Buildings are also often unique entities and their long lifespan, and changes of use during their service life, lead to increased uncertainty about future scenarios. Therefore, although buildings are made up of components which are manufactured products, when assembled together those products create an entity which no longer fits into the logic of manufacturing. Since current views on CE tend to focus mainly on manufactured products, the complexities that are inherent within buildings are often neglected. This paper aims to address such gap.

BUILDING RESEARCH AND CIRCULAR ECONOMIES

Two aspects are worth considering when framing building research from within a circular economy perspective. Firstly, solutions devised and engineered for short-lived products are unlikely to be applicable to buildings. A building's 'manufacture' and useful life extend over a significantly longer time span. Evidence of this can be found in figures about the existing building stock. In the UK, for instance, 80% of the buildings that will be standing in 2050 have already been built (Kelly, 2008) and the average lifespan is 132 years (Ma et al., 2015). If we are to bring about circularity in buildings, focusing on the new ones may not be enough. Secondly, buildings are indeed made of more standardly manufactured products but when these are assembled they create a unique, complex, long-lived and ever-transforming entity. The work of Frank Duffy and Stewart Brand (1994) on the shearing layers of buildings qualitatively highlight this aspect particularly well. From a systemic point of view, buildings can be seen as a meso-level, the macro-level being urban agglomerates and the micro-level building components (Figure 1).

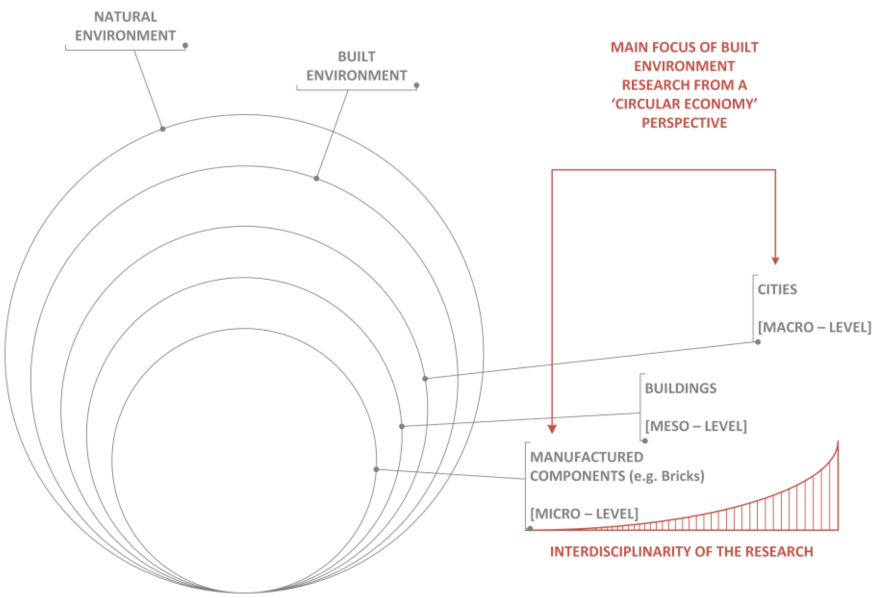

Figure 1 – Framing of built environment research

For the macro-level, research in terms of 'circular economy' is more advanced if one looks into the concept of eco-cities (inter alia Roseland, 1997, Van Berkel et al., 2009), whereas for the micro-level current research on the material dimension (inter alia Braungart et al., 2007, McDonough et al., 2003) and circular Supply Chain Management (SCM) (e.g. Lacy and Rutqvist, 2015) would suffice to bring circularity about. As a result, an element of analysis currently lacking is the building as an entity per se. This somewhat contrasts with mere environmental impact assessment research, most often in terms of embodied energy and carbon[1], which is focussed at building level in nearly half of the cases examined in current literature (Pomponi and Moncaster, 2016).

Figure 1 also shows a qualitative trend of interdisciplinarity in built environment research. From a methodological point of view, an interdisciplinary, if not a transdisciplinary, approach is necessary since the built environment is not a "discrete discipline with its own standard approaches to philosophy, methodology, and methods" (Knight and Turnbull, 2008 p.72). In fact, however, only research at macro-levels (i.e. cities, neighbourhood, built environment) often acknowledge multiple disciplines. One example in this respect is the huge, though UK-centric, Sustainable Urban Environments programme (EPSRC, 2013) which aimed from the outset to have an interdisciplinary focus. At the meso-level (building), the interdisciplinarity is rather moderate, and three main strands are identifiable:

- post-occupancy evaluation (POE) which considers the effectiveness of occupied environments for humans as users (Zimring and Reizenstein, 1980),
- life cycle assessment (LCA) which could be seen as almost entirely techno-numerical although it aims to understand the impacts of human activities on the environment (Crawford, 2011), and
- recent research trends on operational energy which has started moving from technical to techno-social, by including some thoughts about how people actually live in and use the buildings (Janda, 2011).

At micro-level (component), interdisciplinary research is an exception with extremely few cases where the study goes beyond a mere technical point of view (e.g. Forman and Tweed, 2014).

In terms of tools for building research in a circular economy, life cycle assessment (LCA) and material flow analysis (MFA) are well established techniques which have been used also in some CE research (Chen, 2009, Genovese et al., 2015, Ghisellini et al., 2016).

RESEARCH DIMENSIONS OF CIRCULAR ECONOMIES

The main innovation of circular economies consists in decoupling resource depletion and growth, under the idea that an ever-growing economic development and profitability can happen without an ever-growing pressure on the environment. Frosch and Gallopoulos (1989) called for a new industrial paradigm that would transform the linear model into a more integrated industrial ecosystem. Their recommendation embedded inherent circularity, for they suggested effluents of industrial processes should serve as raw materials for other processes, so that "[t]he industrial ecosystem would function as an analogue of biological ecosystems" (Frosch and Gallopoulos, 1989 p.144). This principle resurfaced years later in more defined forms known as biomimicry (Benyus, 1997) and biomimetics

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[1] Defined as the sum of CO_{2eq} emissions related to all activities and components other than the operational energy consumption related to a building's life. More generally, embodied costs may refer different units such as energy, carbon, water, natural resource depletion, etc.

(Bhushan, 2009) which, in their simplest meaning, refer to good design inspired by nature (Pawlyn, 2011).

Biological analogies are often found as well in the prolific work of William McDonough and Michael Braungart (Braungart et al., 2007, McDonough and Braungart, 1998, McDonough and Braungart, 2002, McDonough and Braungart, 2013, McDonough et al., 2003). Their work is perhaps the form of CE most familiar to the wide public. They identified the source of apparent incompatibility between industrial prosperity, environmental harmony, and economic viability in a human-specific activity: design. The role of a different design paradigm can be implicitly found also in Fischer-Kowalski and Hüttler (1998). However when they evaluated the possibility of closing open cycles they concluded that "[u]pon closer scrutiny it is obvious […] that this option applies only to a narrow range of materials and processes" (Fischer-Kowalski and Hüttler, 1998 p.120). A much broader view is instead found in the position of McDonough and Braungart who developed a design framework (best known as cradle to cradle) based on two circular loops, the technical and biological cycles, where resources are kept in for as long as possible, with no or minimal loss of quality and leakage. Their fundamental redesign of industrial flows switches from mainstream eco-efficiency (doing less bad) to eco-effectiveness (doing good).

A similar scepticism over an ever greater efficiency as a pathway to sustainability is argued by Ulanowicz et al. (2009) who used information theory to quantitatively call for caution in maximizing efficiency in any field, whether it is physics, economics, or ecology. The reasoning underpinning their method of analysis may resemble the biomimicry philosophy at a first look but it bears a fundamental difference. While biomimicry suggests learning from nature to inspire design, Ulanowicz et al. (2009) encourage us to transfer our understanding and modelling of natural elements (such as ecology and ecosystems) to more human concepts such as economies. This is clarified in later work by the same authors (Goerner et al., 2009 p.76) where a measure called Quantitative Economic Development (QED) is developed to provide a mathematical basis to support "current theory [which] fails to differentiate healthy development from mere growth". Overall, they use System Science as the method of analysis for a sustainable economic development since "similar energy concepts and network analysis methods can be applied to all matter-energy-information flow systems because […] such systems exhibit strong parallels in behavioural patterns and developmental dynamics" (Goerner et al., 2009 p.76-77).

Current critiques to the CE account it responsible for a sometimes simplistic approach which does not really address societal and political challenges or the complexity of human nature. These views resonate with the words of Gregson et al. (2015 p.219) who argue that academics and practitioners tend to use the CE concept in an "approbatory, uncritical, descriptive and deeply normative" fashion. CE can therefore appear dogmatic (Bakker et al., 2010) in the belief that having devised a solution implicitly means having solved the problem. Such strong faith in the effectiveness of a technical fix (Amelung and Martens, 2008) resembles the truth claims of the positivistic philosophy of science which neglects the interdependence between knowledge production and social origins of belief (Dolby, 1971). More recent trends, however, see scientific research as a value-laden activity (Gonzalez 2013). One example is the perspective on resource consumption offered by Sauvé et al. (2015 p.4) who believe that humans "will certainly pursue the means to find and extract increasingly rarer and more expensive resources with ever increasing fervour and cleverness".

A broader view on CE can be found in the work of Naustdalslid (2014) who pairs policy and societal dimensions with the technical one and warns that an excessive focus on materials and their optimisation may underestimate the key role of stakeholder involvement and societal participation to implement CE successfully. The role of society emerges also in a broad discussion on the necessary system perspective for CE by Webster (2013) who emphasises the fundamental part played by education. The need for moral and psychological adjustments was already very clear half a century ago to Boulding (1966) who saw them as indispensable and instrumental in the transition to an embryonic version of CE, which he called closed sphere. As a precursor of the importance of flows and connections underscored by Webster (2013), Boulding (1966) already believed that knowledge (or information) was far more important than matter because, in his view, matter only acquires meaningfulness to humans when becomes the object of our knowledge. A further dimension seldom considered in framing the CE is the behavioural one. This has been flagged by Smith (2014) who recognises the crucial role of behavioural studies, "even before we arrive at design and repair because it may be the case that people do not want to repair that specific thing". A behavioural dimension for circularity, although in a customer-centric perspective, also emerged in the review of Ghisellini et al. (2016) who reflect on collaborative consumption models.

However, not all scholars see social and behavioural issues as part of circular economies. An example is the framing of Sauvé et al. (2015) who do not see CE as having any social objectives, but rather as a system which focuses on reuse and recycling as substitutes for raw virgin materials. To enable these flows of materials and resources whilst guaranteeing economy growth, some scholars see a key role in the broad spectrum of sustainable supply chain management thus awarding a predominant role to the economic dimension (e.g. Genovese et al., 2015, Lacy and Rutqvist, 2015). A further important aspect is the role of policy towards successful circular economies, as discussed by Geng and Doberstein (2008) who identify barriers and challenges in terms of technology and public participation. Barriers are also one of the points considered by Genovese et al. (2015) who see government bodies as facilitators to overcome them in economic and industrial systems. The opportunities for policymakers to implement CE are also discussed in Esposito et al. (2015) who look at the practical levers such as tax, laws and regulatory frameworks within specific industrial sectors or the society at large. Regarding the latter group, however, a very western-centric view emerges in Esposito et al. (2015 p.2) who see the ultimate goal of a CE as "to preserve *our* current way of life by making it technically viable for the longer term by producing within a closed system" [our italics]. This statement neglects the fact that there is no such thing as a *global* current way of life but rather a very comfortable life in developed countries which we want to hold to as tightly as possible. A concept, which resonates with the views of Gregson et al. (2015 p.236) who see CE "as a form of geo-political insurance; in a world where rampant economic growth in the developing world threatens the stability of economies long accustomed to having resources their own way". A similar viewpoint comes from Kerschner (2010) who reflected on the popularity that de-growth (*decroissance*) concepts (see e.g. Georgescu-Roegen, 1977, Latouche, 2007) regained a few years ago and concluded that economic de-growth and growing economy are not mutually exclusive but, in fact, complements, where "de-growth is not a goal in itself, but the rich North's path towards a globally equitable South" (Kerschner, 2010 p.544). Table 1 shows a meta-analysis of the dimensions identified in the circular economy literature.

Table 1 – Meta-analysis of seminal literature reviewed for this research

	Econ.	Environ.	Tech.	Society	Gov.	Behav.	**TOT.**
Frosch and Gallopoulos (1989)		x	x				2
Benyus (1997)		x	x				2
Bhushan (2009)			x				1
Braungart et al. (2007)	x	x	x	x			4
McDonough and Braungart (1998)		x	x				2
McDonough and Braungart (2002)		x	x				2
McDonough and Braungart (2013)	x	x	x	x			4
McDonough et al. (2003)	x	x	x				3
Fischer-Kowalski and Hüttler (1998)			x	x			2
Ellen MacArthur Foundation (2013)	x	x	x	x			4
Ulanowicz et al. (2009)	x	x		x			3
Goerner et al. (2009)	x	x		x			3
Webster (2013)	x	x	x	x			4
Huamao and Fengqi (2007)	x	x	x	x			4
Gregson et al. (2015)	x	x	x				3
Sauvé et al. (2015)	x	x	x	x			4
Naustdalslid (2014)	x			x	x		3
Boulding (1966)	x	x	x	x			4
Genovese et al. (2015)	x	x	x		x		4
Lacy and Rutqvist (2015)	x		x		x		3
George et al. (2015)	x	x		x			3
Smith (2014)				x		x	2
Ghisellini et al. (2015)	x	x	x	x			4
Anderson (2007)	x	x	x	x			4
Geng and Doberstein (2008)	x	x	x		x		4
Esposito et al. (2015)	x	x	x		x		4
TOTALS	19	21	21	15	5	1	

THE PROPOSED FRAMEWORK

The previous section has shown how authors from different disciplines view CE differently. In rare cases, the focus on CE was mono-dimensional whereas we often found a link to the three pillars of sustainability: economy, environment, and society. Building on the literature reviewed, we however believe that at least three more defining elements are missing from the triple bottom line view and these are: the role of governments (i.e. policy), the role of matter (e.g. design, technology, materials), and the role of individuals (i.e. behavioural). All of these are pivotal for the success of a global system such as CE, and in fact all three of them have been in more or less explicit ways mentioned in the current literature on the topic. Figure 2 presents our proposal for a frame of reference for building research from within a CE perspective. Our belief behind a 'six pillars' framework is that to meet successfully the goals of today's sustainability research it is necessary to combine the use of different disciplines, such in transdisciplinary research (Kajikawa et al., 2014).

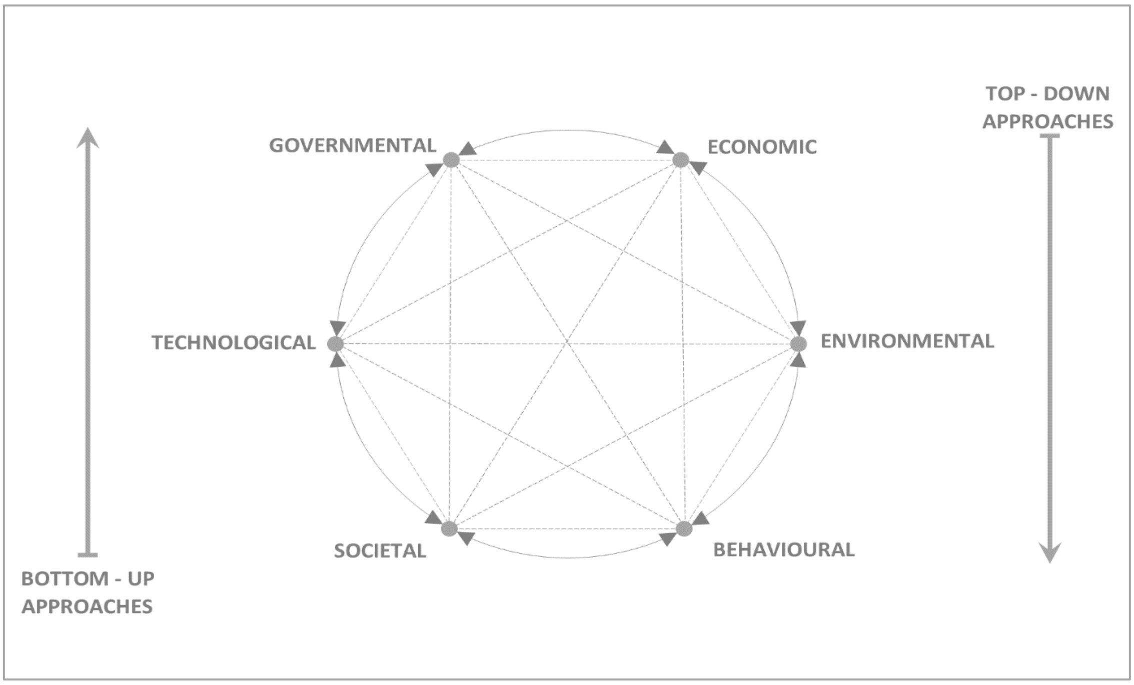

Figure 2 - Frame of reference: six dimensions for building research in a circular economy

Firstly, the peripheral arrowed arcs represent the need for a holistic approach and a harmonized collaboration of research initiatives in each of the six pillars. Secondly, the inner dashed lines stress the importance of practical links between each pillar and the others. In some cases, indeed, not all research dimensions may be needed in practice and the framework also allows for sub-groups of two, three, four, and five dimensions. We now discuss each dimension in turn with practical examples from current discourse on circular economy and built environment after the authors attended relevant events in London throughout end of 2015/early 2016 themed around the topic.

Governmental dimension

In discussing the barriers to steel reuse in construction, Roy Fishwick (Corbey et al., 2016) highlighted the role that policy can play as current market prices for steel are so low that steel reuse is hardly economically viable. Additionally, he reported on lack of will at EU regulatory level that could kill steel reuse. At a smaller geographical level, Cécile Faraud (2016) reported on initiatives of planning authorities to achieve circular economy. Her contribution was tailored around the aim of Peterborough in England to become a circular city, and she stressed the difference between Peterborough and the initiatives of worldwide metropolis. Indeed, whereas cities like Amsterdam, Glasgow and Copenhagen are applying circular economy principles to cities, Peterborough believes that a circular city is the pathway to a circular economy (Faraud, 2016). She also stressed the need for planning authorities to be locally accurate, i.e. to have strong focus and deep roots in their specific context to make sure they understand the diversity and peculiarity of the challenges ahead (Faraud, 2016). Katherine Adams (2016) discussed the importance of tax breaks if a bigger share of reclaimed material use in buildings is to be achieved.

Economic dimension

The need to change current ownership models and develop a different paradigm for profitability has been a recurring topic in the presentations attended (e.g. Chamberlin, 2015, Cheshire, 2016, O'Connor, 2015). David Cheshire (2016) used the example of lighting systems that are not owned by the building owner/occupier anymore, who just pays for the lighting service through an agreement that also includes performance. Similarly, he discussed other case studies of buildings where collaborative models between all contractors and sub-contractors involved were used from the outset rather than basing the choice of such key actors on the cheapest tenderer at the end of the supply chain (Cheshire, 2016). Similarly, Erica Purvis (2015) encouraged more collaborative business models and more openness about relevant data to promote quicker feedback/feed-forward loops.

Environmental dimension

Research in this respect stresses the lower environmental impacts that reuse has over new products, such as in the cases of steel (Corbey et al., 2016) and wood (Adams, 2016). Moreover, most of current research on built environment sustainability focuses on whole life energy and carbon as impact categories (Pomponi and Moncaster, 2016) but such an approach might miss out on other, equally crucial, environmental indicators with the risk of shifting environmental burdens from one impact category to another (Pomponi et al., 2016). Therefore, whilst an endless list of environmental indicators is neither desirable nor necessary, a set representative of the majority of environmental impacts should be used nonetheless. (Steinmann et al., 2016).

Behavioral dimension

The behavioral dimension, seldom mentioned in CE literature, emerged instead as a key element for a breakthrough in built environment sustainability. It was identified as instrumental to succeed in the uptake of recycling (Overbury, 2015), energy and carbon reduction (Daly, 2015), knowledge on low-carbon buildings and technologies (Fieldhouse, 2015), and people's attitude towards reused material (Khoo, 2015, Overbury, 2015, Adams, 2016, Corbey et al., 2016, Owens, 2016). Similar issues are also encountered in furniture sharing and reuse (Beavis, 2015, O'Connor, 2015). Specifically, Roy Fishwick (Corbey et al., 2016) see behavioural issues as one of the two biggest threats to CE uptake and steel reuse in buildings as, in his own words, "people do not want to buy steel for their brand new shiny building from the scrapman". Quite to the contrary, Adams (2016) reported that attractiveness and aesthetic scored as top criteria for people to choose reclaimed wood, which highlights different behavioural patterns depending on the material under consideration. Therefore, there is a strong need to accelerate behavioural research in built environment sustainability as it seems it will eventually be people, not technology, the key to embrace a circular paradigm.

Societal dimension

Some refer to the circular economy as the sharing economy. Regardless of whether that is fully true or not, it highlights the strong social roots that a circular economy must have. This often involves partnerships and collaboration in building projects (new and existing) and a wider engagement with all involved stakeholders (Daly, 2015), networks for resource sharing and reuse (Faraud, 2016, Beavis, 2015), and a different approach to building's design (Cheshire, 2016, Greenfield, 2016). In the literature review we have seen that education will have to play a crucial role and this seems specifically important if new building designers have to learn to build with reused and reclaimed materials.

Technological dimension

Technology emerges as a key aspect to enable circular loops, to connect demand and supplies and to handle, store, and manage huge quantity of data that a circular economy requires. Examples in this latter case are online platforms and web-based apps for resource sharing (Khoo, 2015, O'Connor, 2015, Owens, 2016). Technological innovations in manufacturing and operations can also have enormous impacts, such as mortar-less 3D printed bricks and cardboard ductworks (Cheshire, 2016), Design for Manufacture and Assembly (DfMA) (e.g. Laing O'Rourke, 2016), or Design for Deconstruction or Disassembly (DfD) (e.g. Densley Tingley and Davison, 2011, Adams, 2016) – just to name a few.

In addition to the six dimensions discussed our framework also includes both bottom-up and top-down approaches as boundary conditions. Examples of top-down approaches are CE programs at EU level (WRAP, 2013) or programs developed by planning authorities at city scale (Faraud, 2016). Bottom-up initiatives have equally proven their effectiveness such as the case of grassroots innovations for circular economies (Charter and Keiller, 2014, Smith, 2014). One further important aspect is that real actions and concrete proposals for a different approach are mostly available from within the technological dimension and, to a lesser extent, in terms of governmental and policy frameworks and environmental assessment metrics. The greatest challenges that lie ahead will deal with the role of people, both as individuals and as society as a whole, and that of new economic models to promote and implement circularity. As such, interdisciplinary research is best placed to succeed in that goal as it will naturally consider multiple dimensions of analysis that switch the narrow focus of technicalities for a wider research basis, without sacrificing depth for breadth. One overall example is the durability of houses and buildings where the problem is not merely technical. In fact, is not technical at all. The Pantheon was built in 117AD, and it is still usable and indeed used today. Yet, despite a steady technical development, housing and building construction has severely declined in durability (Boulding, 1966). As Boulding (1966 p.12) worded it, "I suspect that we have underestimated, even in our spendthrift society, the gains from increased durability". Current technology would certainly allow us to build more durable buildings, and the benefits for the environment in terms of resource conservation and waste reduction are undeniable. And yet, there are numerous cases of buildings of 30/40 years that are being demolished (e.g. Cheshire, 2016). Building research will have to engage with all relevant stakeholders to understand why it is so, and the reasons behind believing that demolishing such 'baby' buildings is a reasonable choice. Most likely, the answers will be multiple and complex and therefore the contributions that different disciplines can offer are pivotal to achieve a real understanding.

CONCLUSIONS

The built environment is the sector which puts the most pressure on the natural environment and its role in transitioning to a circular economy is pivotal. In framing building research from within a circular economy perspective we have identified a lack of focus on buildings per se, as unique entities. It also emerged a decrease in interdisciplinary research related to the scale of analysis. We have therefore framed the problem on a three-tier level: macro (cities and neighbourhoods), meso (buildings) and micro (assemblies and components, e.g. bricks). To understand in which ways building research could be shaped by the circular economy we have reviewed seminal literature on CEs with an aim of identifying the fundamental dimensions of CE research from within different disciplinary backgrounds. The outcome of the literature review and its meta-analysis have represented the basis for the framework we developed which includes 'six' pillars for building research. These research dimensions have then been tested against recent contributions to the discourse on circular economy and the built environment. All dimensions could be identified in current initiatives, ideas, and approaches to achieve more 'circular' buildings therefore showing some robustness of our framework. However, it also emerged a rather poor interdisciplinary underpinning to orchestrate harmoniously and address effectively the six dimensions. We therefore encourage an increase in interdisciplinary research initiatives about buildings and circular economies. Evidence from practical examples have indeed shown that the greatest challenges ahead lie not in further technological innovation but rather in the role of people, both as individuals and as a society.

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